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A Comparison of Fijian Honeyeaters Abundance and Foraging Behaviour at USP Laucala Campus and Colo-I-Suva Forest Reserve.

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Abstract

Forests are increasingly becoming fragmented and declining due to natural causes and human-induced activities. The latter creates an imbalance which put the survival of vulnerable species such as those of avifauna at risk. Honeyeaters are group of birds common in Fiji, with certain species strictly confined to specific habitats. This study is an attempt to compare the abundance and foraging behaviours of three sympatric honeyeaters namely Kikau wattled honeyeater, Orange-breasted myzomela and Giant honeyeater at two contradicted sites (USP campus and Colo-i-Suva Forest Reserve). The survey was carried out using point count method along three different transect routes of approximately 2 Km on each study sites . A higher species diversity and abundance was observed in Colo-i-Suva Forest Reserve than in USP campus. Kikau wattled honeyeater are more populated at USP campus due to adequate nectar-producing plants. Whereas both Orange-breasted myzomela (highly adaptable bird species) and Giant honeyeater (forest specifics) are frequent in Colo-i-Suva Forest Reserve. All exhibited a wider range of foraging techniques across forest vertical strata and plant species, except for Giant honeyeater (not observed). The statistical analysis showed that there is a significant difference ($p < 0.05$) in abundance as well as between the number of honeyeater species in both sites across the forest vertical strata. However, there is no significant difference in the foraging behaviour and the number of honeyeaters found foraging on diverse plant species ($p > 0.05$).

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Keywords: Honeyeater, foraging behaviour, diversity, human activity, avifauna

1. Introduction

Considering the looming ramifications of globalization, natural habitats are being modified or replaced with build structures, thus having a tremendous influence on biodiversity (McKinney, 2008; Meffert & Dziock, 2013). Avifauna are widely recognised as indicators of overall biodiversity and sustainable development due to their high mobility and habitat sensitivity (Titoko *et al.,* 2019; Watling, 2013). Studies of bird distribution have highlighted a decrease in species richness (Chace & Walsh, 2006; Marzluff, 2001; Meffert & Dziock, 2013) and increase of introduced species (Clavero *et al.,* 2009) in highly urbanized environments. On the contrary, a consistent positive correlation occurs between species richness and green spaces in urbanized zones (Chaiyarat *et al.,* 2019; Dale, 2018). In tandem to this, climate change further exacerbates this issue with negative connotation on birds seasonal timing including breeding and migration through changes in climatic conditions (Carey, 2009).

Fiji's avifauna are diverse and hold significant cultural value (Watling, 2013). About 34 of the known 66 land bird species characterized in Fiji are endemic, with majority residing in the forest (Reid *et al.,* 2019), but knowledge regarding their ecology and behaviour remains rare (Naikatini *et al.,* 2022). It has been documented that more than 60 % of Fiji's native forest was deforested, creating a mosaic of primary and secondary forest (Olson *et al.,* 2010). Among other prominent bird species in Fiji, honeyeater species were consistently exposed to habitual stress. Honeyeaters are speciose group of birds which belong to the family Meliphagidae with diverged niche, body size and distribution (Andersen *et al.,* 2014; Hay *et al.,* 2022). They have a unique morphological and behavioural feature that enable them to manoeuvre in a backward direction. Despite their habitual feeding preference for nectar, most of them are flexible or generalised feeders, preying on insects and arthropods for protein nourishment during breeding and moulting season (Norman & Christidis,

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2013; Recher & Davis, 2011). Honeyeaters exist as habitat specialists and generalists. Although they are ecologically and morphologically diverse, those that are nectarivore's have physiological constraints in adapting to new habitats (Norman & Christidis, 2013). Like other bird species, honeyeaters have adapted to inter- and intraspecific competitions. The latter prolong their co-existence and survival (Fulton, 2021). Fiji has several distinct honeyeater species including Kikau wattled honeyeater (*Foulehaio procerior*) and Fiji wattled honeyeater (*Foulehaio taviuensis*), Giant honeyeater (*Gymnomyza brunneirostris*), Yellow-billed honeyeater (*Gymnomyza viridis*), and Orange-breasted Myzomela (*Myzomela jugularis*) which are sparsely distributed. Others such as the Kadavu honeyeater (*Xanthotis provocator*), and Rotuma Myzomela (*Myzomela chermesina*) are restricted to Kadavu and northern islands of Rotuma respectively in Fiji's archipelago (Andersen *et al.,* 2014; Yabaki *et al.,* 2016).

Presented with these aforementioned circumstances, the present study attempts to study three sympatric honeyeater species for their abundance and foraging behaviours at two contradictory sites. Site 1 (disturbed site) has encumbered food resource and less protection for its habitants. Site 2 (less disturbed site) offers more protection and a wide range of food options. Hereinafter, the proposed sites are represented as; site 1 (The University of the South Pacific Laucala campus) and site 2 (Colo-i-Suva Forest Reserve). This study aids in collecting significant data which predicts the extent to which human activities have on honeyeater species in terms of their abundance and foraging behaviours. The objective of this study is to analyse and compare the abundance and foraging behaviours of honeyeater species in urban vegetation and primary forest.

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2. Methodology

2.1 Site description

The survey was conducted at the University of the South Pacific Laucala campus (18° 8′ 883′S and 178° 26′ 857′E) and Colo-i-Suva Forest Reserve (18° 3′ 583′S and 178° 27′ 498′E). Both locations are geographically situated in the southeast part of Viti Levu, Fiji. The University of the South Pacific Laucala campus has lesser density of tree cover within its boundary, mainly comprise of angiosperms. Given its location, which is represented as an open habitat, constantly disturbed by human activities. Figure 1 outlines three different transect routes (A, B and C) within USP Laucala campus which has been surveyed.

Figure 1. Sites surveyed in USP Laucala campus

Colo-i-Suva Forest Reserve is one of Fiji's natural and national heritage, an oasis of lush rainforest teeming with tropical plants and diverse bird species. It spans 3.7 Km^2 of native land that was leased and gazetted for conservation purposes to counteract aggressive logging practices. Approximately, 25% of the reserve (92 hectares) is declared as the Colo-i-Suva forest park, now recognized as a

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conservation and eco-touristic site (Naikatini *et al.,* 2022). Most of the trees colonizing the area are introduced mahogany (*Swietenia macrophylla*), however native tree species have regenerated overtime (Naikatini *et al.,* 2022). Figure 2 shows three different transect routes (A, B and C) within the Colo-i-Suva Forest Reserve which has been surveyed.

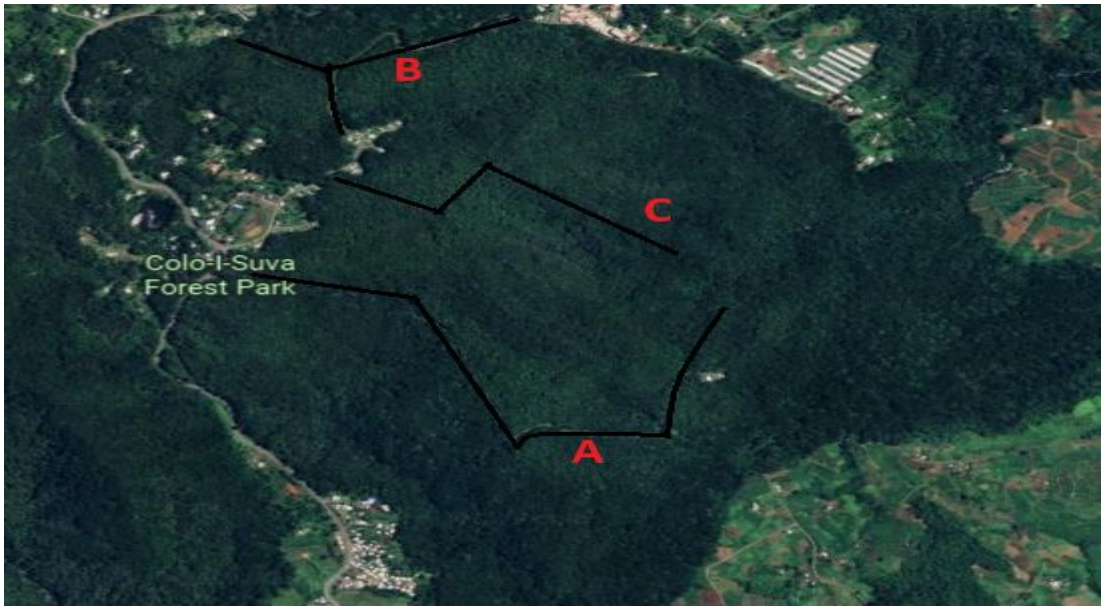

Figure 2. Sites surveyed in Colo-i-Suva Forest Reserve.

2.2 Bird count and foraging observations

Three sympatric species of honeyeater viz Orange-breasted myzomela (*Myzomela jugularis*), Kikau wattled honeyeater (*Foulehaio procerior*) and Giant honeyeater (*Gymnomyza brunneirostris*) were surveyed from the proposed sites. Field surveys were conducted for 3 weeks between the month of August and September as Fijian birds are more readily observed during their breeding season (June to September) (Naikatini *et al.,* 2022). In each site, three replicates were conducted for higher precision of results. The survey routes were positioned at different locations within each survey sites to avoid surveying the same location. Observation were made with Bushnell Power 8 x 30 binoculars and a GPS (Global Positioning System) was used for navigation purposes. Point count was conducted in the morning between 6 am to 10 am to capture peak bird activity. The data was collected at 10 different sites

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with 200 m intervals along a unidirectional transect that stretches for 2 Km. Within the 200 m intervals, a 50 m radius was estimated which was regarded as the working area and all the honeyeater species found and heard within this area were recorded. A radius of 50 m is appropriate since it obviate the setbacks of having less or large observatory radius. 15 minutes were allocated for each of the sites. The first 5 minutes were spent to record honeyeater species heard and seen in the area of study. The next 10 minutes were used to observe the foraging techniques of the bird species; what they feed on, microhabitat on plant, species of plant they perch on and the estimated height of the perch site above the ground were recorded (SFigure 1).

2.3 Data analysis

The abundance of honeyeater species in both survey sites was calculated in each transects using the formula; (D = (n/A)/m) where D equals to the density per Km^2, n is the total number of individual species counted within the plot, A is the total area of the 50 m radius, and m is the total number of area searches along the survey routes. Tukey's test was employed to analyse the abundance of the honeyeater species to compare the means of the three different variables. Additionally, the different foraging techniques displayed by the studied honeyeater species was analysed using chi-square test to identify existing association between two different variables. Furthermore, analysis of stratification and plant species were scrutinized using the Fisher's test due to low data availability.

3.0 Results and Discussion

The composition of the two sites (site 1 & 2) varied in topography and degrees of human disturbances. Results obtained from this study showed that Orange-breasted myzomela and Wattled honeyeater are present in both study areas with diverse foraging behaviours observed on different forest vertical strata and plant species. However, there were no data analysis for the mentioned variables of Giant forest honeyeater foraging behaviour due to their undetectability on sight.

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3.1 Abundance and diversity

Analysing the species richness of avifauna in a particular environment is very important. Although it is not the current project primary focus, a small-scale analysis of bird's species richness and abundance was conducted to give a fair representation of bird's diversity from the two study sites. Further, it provides an insight on the health of the two sites in terms of biodiversity. A high species richness is seen in Colo-i-Suva Forest Reserve (site 2) compared to USP Laucala campus (site 1) as recorded in Table 1. This result agrees with other studies (Tu *et al.,* 2020), due to the availability of resources such as space and nutriment, coupled with less human environmental intervention as shown in site 2 than site 1. A total of three endemic, nectarivore honeyeater species were recorded in this study, namely Kikau wattled honeyeater (*Foulehaio procerior*), Orange-breasted myzomela (*Myzomela jugularis*) and Giant honeyeater (*Gymnomyza brunneirostris*). The Orange-breasted myzomela and Wattled honeyeater are more widespread, inhabiting almost all terrestrial habitats in Fiji (Naikatini *et al.,* 2022). Conversely, Giant honeyeater are more reserved and cryptic in nature, thus are confined to intact mature primary forests (Naikatini *et al.,* 2022). This agrees with our results where the species is only recorded in Colo-i-Suva Forest Reserve (Figure 3).

From the two sites, Wattled honeyeaters are highly abundant in USP campus with an estimated density of nearly 2,500 birds per square kilometres (Figure 3). The diversity and richness of plant communities, particularly those classified as angiosperms have attracted and sustained bird's survival. Given the high number of nectar-producing plants concurrent with blossoming season, there is adequate resources for nourishment which resulted in their higher abundance. In contrast, a lower population is seen in Colo-i-Suva Forest Reserve due to scarcity of flowering plants, thus engendering less food options for these energetic feeders. On the other hand, Orange-breasted myzomela are more populated in Colo-i-Suva Forest Reserve with an estimated bird density of more than 500 birds per kilometres (Figure 3). They are generalized feeders and are able to explore a wide range of niches, hence

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can thrive and survive in various environments. Given their adaptability, their abundance in site 1 is almost as similar to site 2. Giant honeyeater are forest specifics (only recorded in Colo-i-Suva Forest Reserve), with an estimated population less than 500 birds per kilometres (Figure 3). Tukey HSD test showed that the pairwise comparison of honeyeater abundance from the two study sites were statistically significant ($p < 0.05$).

Table 1. Species richness of birds at USP campus and Colo-i-Suva Forest Reserve

Location	Species Richness
USP campus	17
Colo-i-Suva Forest Reserve	25

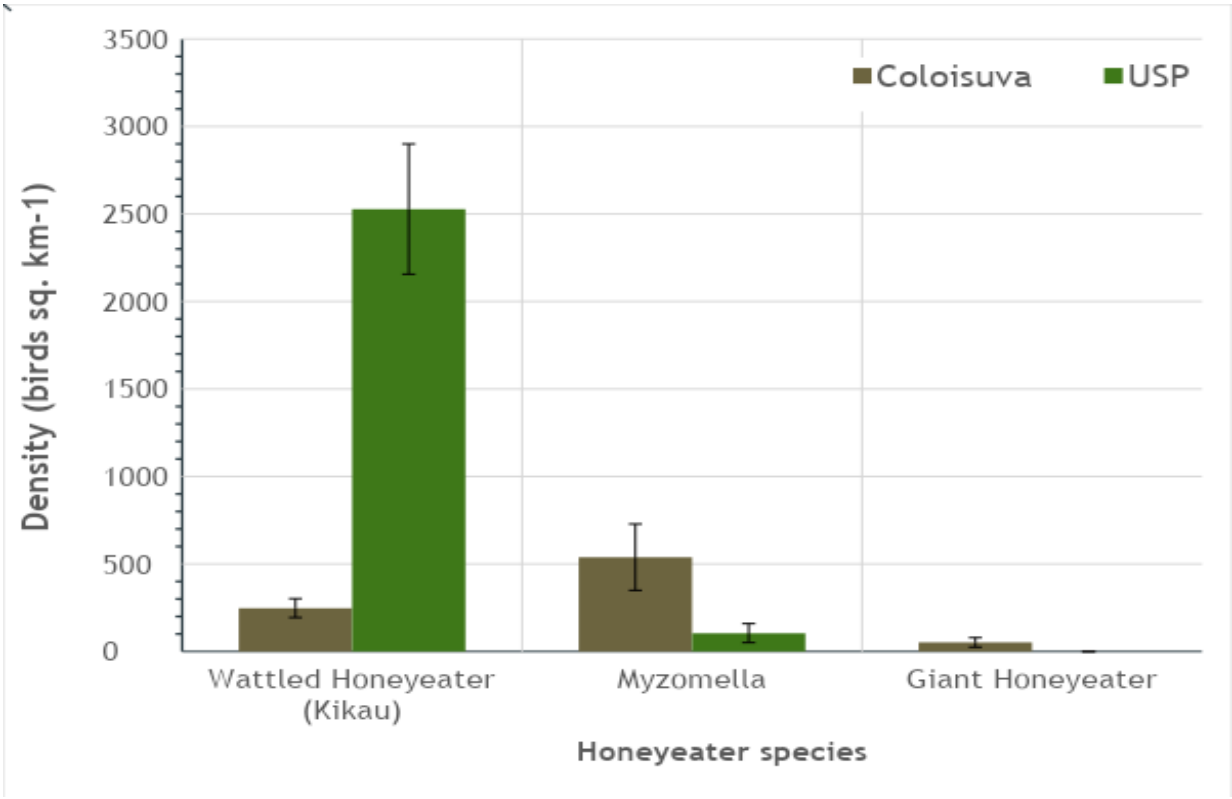

Figure 3. Density of honeyeater species at USP campus and Colo-i-Suva Forest Reserve.

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3.2 Foraging behaviour

Generally, nectarivores like honeyeaters selectively forage on flowers with high nectar contents particularly to get sufficient energy required for their physical and biological processes (Abrahamczyk & Kessler, 2015; French *et al.*, 2005). Nectar is an aqueous solution that comprise of sugar with traces of amino acids and electrolytes (Nicolson & Thornburg, 2007), thus are consumed by honeyeaters in larger amount. This justifies the wide range of foraging techniques displayed by the honeyeaters. Sally and gleaning were the dominant foraging behaviour used by Orange-breasted myzomela and Wattled honeyeater respectively in both sites (Figure 4 & 5). A typical behavioural trait displayed by both Orange-breasted myzomela and Wattled honeyeater is fighting. This habitual aggressive behaviour (Ford, 2001) depicts intra- and inter-species competition for resources. Statistical analysis indicates no significant difference between the foraging behaviour of both honeyeater species from the two sites ($p > 0.05$).

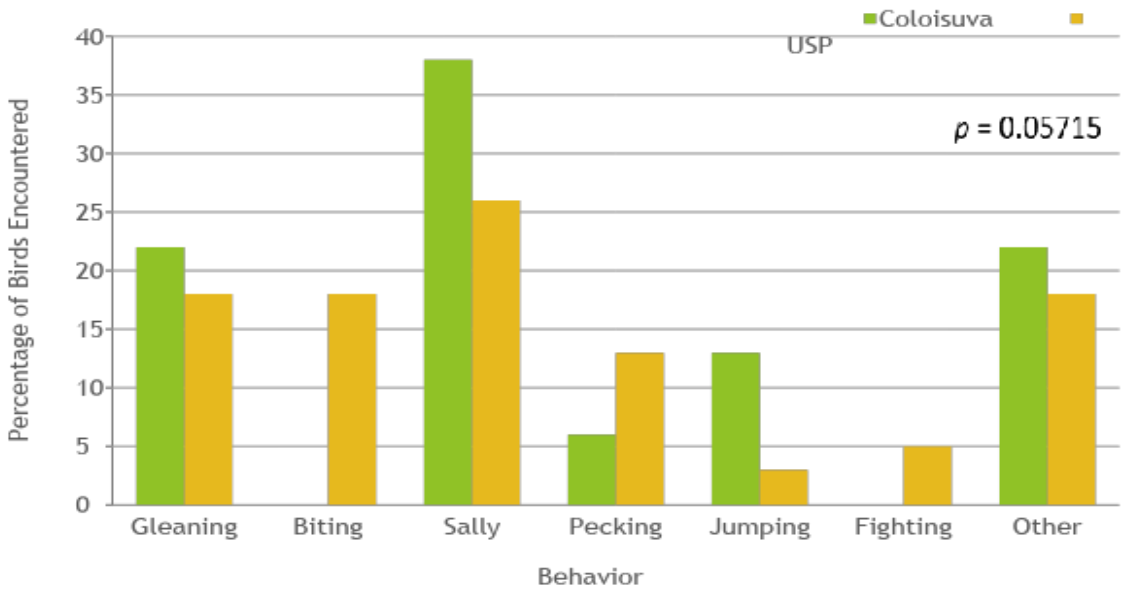

Figure 4. Foraging behaviour of Orange-breasted myzomela at USP campus and Colo-i-Suva Forest Reserve.

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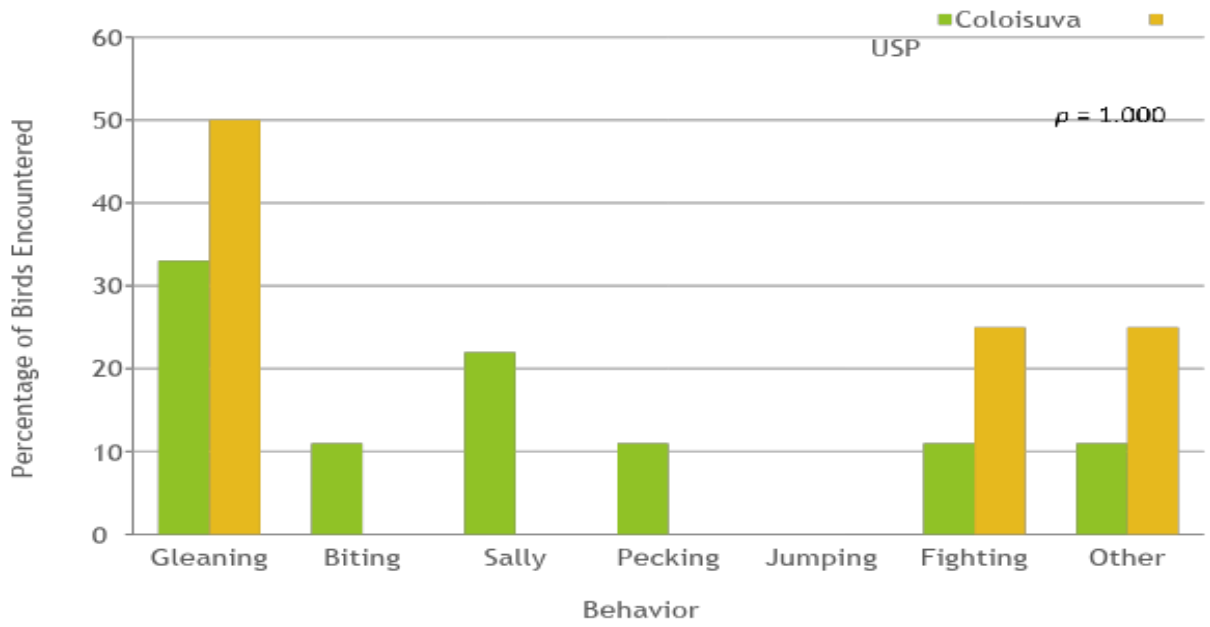

Figure 5. Foraging behaviour of the Wattled honeyeater at USP campus and Colo-i-Suva Forest Reserve.

3.3 Foraging forest vertical strata

Forest vertical structure influences the distribution of resources and species biology (Long *et al.,* 2021). This study categorises forests vertical layer into four strata: the undergrowth layer (3-5 m), sub-canopy (6-17 m), canopy (18-29 m) and the emergent forest layer (30 m and above). Both species of honeyeater differed significantly in foraging height. Giant honeyeater usually occupied the canopy, Wattled honeyeater in the mid-canopy and Orange-breasted myzomela in the lower canopy. When all species concurred at a forest habitat, vertical foraging reduces intra- and inter-specific competition as reported in other studies (Mansor *et al.,* 2020; Oliveira & Scheffers, 2019). In the absence of competing species with respect to foraging height, honeyeaters freely manoeuvre across higher vertical strata (Figure 6 & 7). A Fisher's exact test count for the data indicates that there is a highly significant difference in foraging height among Orange-breasted myzomela ($p = 0.0006567$) and Wattled honeyeater ($p < 2.2e^{-16}$). More than 60% of Orange-breasted myzomela observed in Colo-i-Suva Forest Reserve forage within sub-canopy and canopy layers due to

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optimum living conditions in terms of nourishment and less competition for resources. In tandem to this, conspecific species (> 50%) observed at USP campus predominately forage within the sub-canopy, followed by the undergrowth layer (> 20%) because most angiosperm flourish in these strata (Figure 6). Additionally, all Wattled honeyeaters recorded in Colo-i-Suva Forest Reserve prefer foraging on sub-canopy and canopy layer. There were no species observed in the emergent strata possibly as a survival strategy to avoid predatory species such as Fiji goshawk (*Accipiter rufitorques*) or other territorial honeyeater (Giant honeyeater). However, 40% of this species of bird's forage on undergrowth layer at USP campus, while 60% forage beyond (Figure 7).

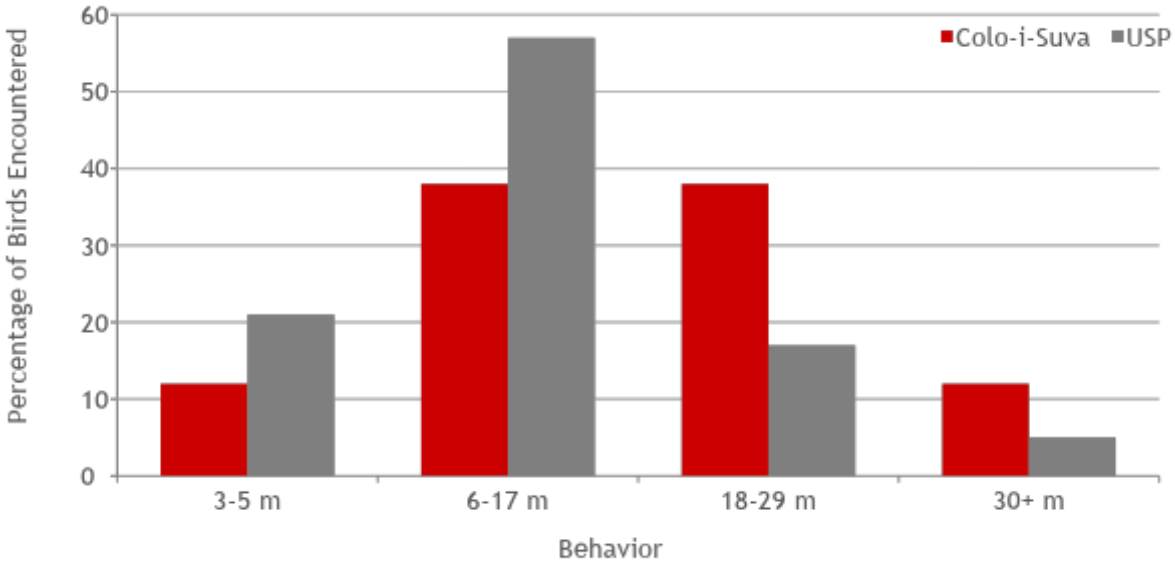

Figure 6. Foraging of Orange-breasted myzomela across forest vertical strata.

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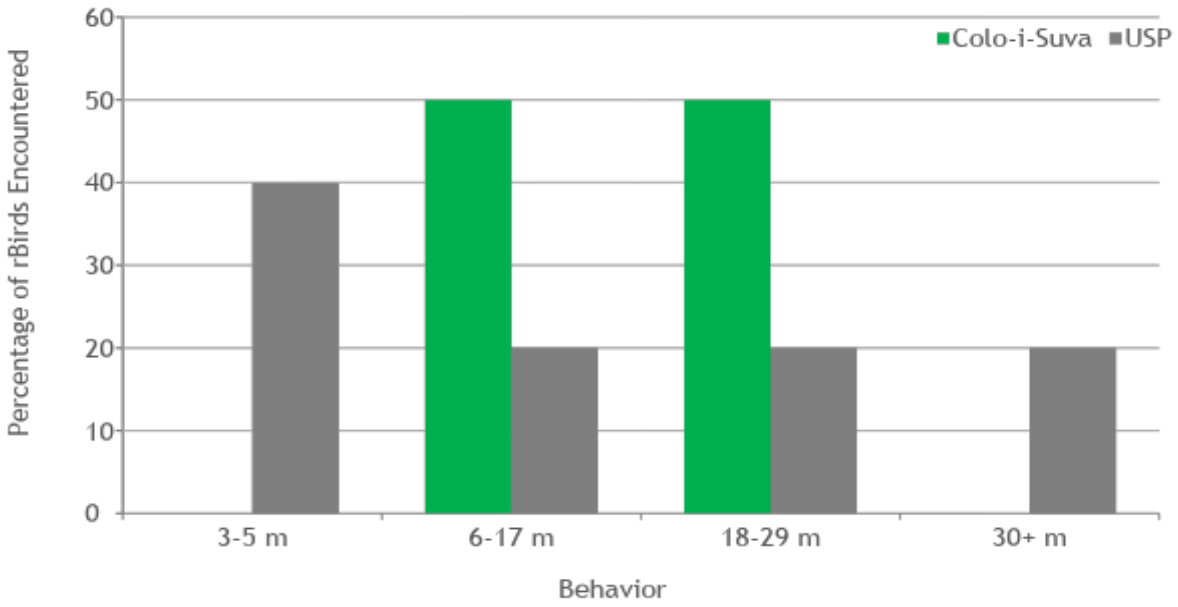

Figure 7. Foraging of Wattled honeyeater across forest vertical strata.

3.4 Plant species foraged

Vegetation density and richness coupled with food availability create ideal foraging sites for avifauna species (Rajpar *et al.,* 2018). The type and number of trees a bird species foraged on gives a good representation of the species dietary habits. Both study areas differed in foraging plants. Most plant species were foraged by Orange-breasted myzomela compared to Wattled honeyeater. This observation is true for both survey sites (Figure 8 & 9). As demonstrated in Figure 8, a total of 13 different plant species were identified, with higher foraging activity of Orange-breasted myzomela (> 30%) on rain tree (*Samanea saman*). Approximately 25% of Wattled honeyeater were equally observed across few flowering plants including mango tree (*Mangifera indica*), red bead tree (*Adenanthera pavonina*), rain tree (*Samanea saman*) and palm tree. More than 50% of both species of honeyeater were recorded to forage on mahogany (*Swietenia macrophylla*) at Colo-i-Suva Forest Reserve (Figure 9). A Fisher's exact test count indicates no statistical difference in the percentage of birds found foraging on different plant species from the study areas ($p > 0.05$).

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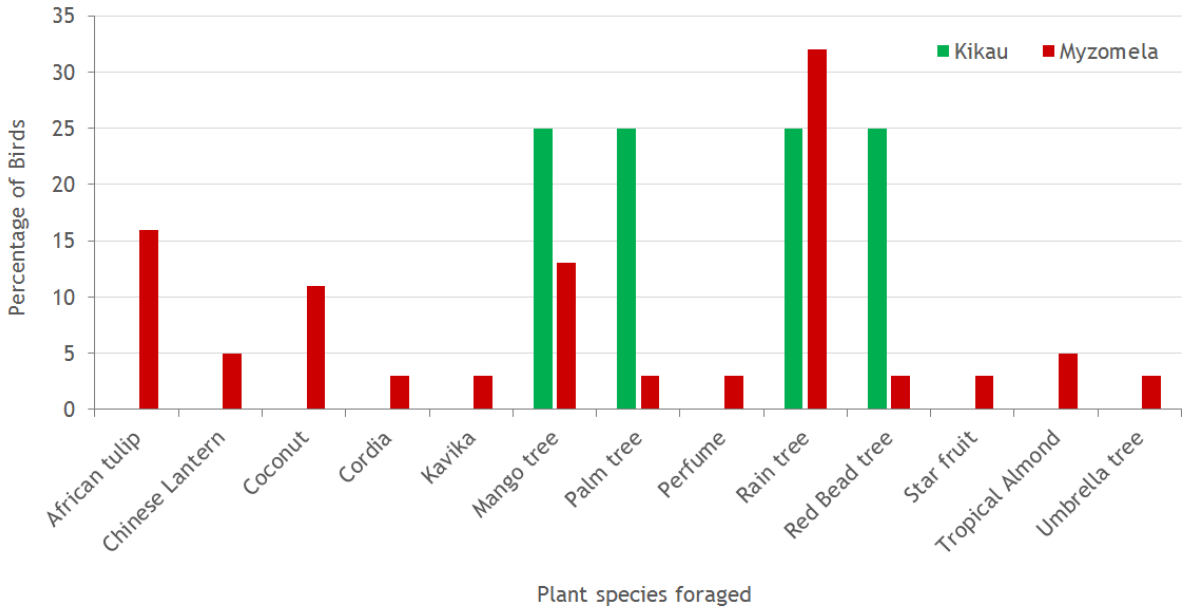

Figure 8. Foraging of honeyeaters on different plants at USP campus.

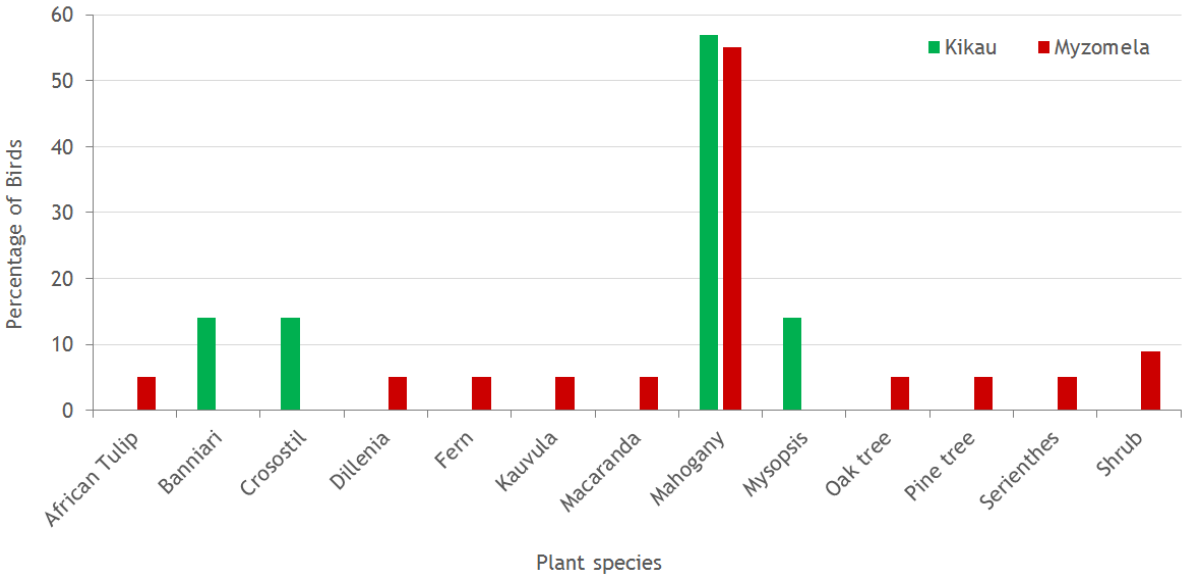

Figure 9. Foraging of honeyeaters on different plant species at Colo-i-Suva Forest Reserve.

4. Conclusion

Three sympatric species of honeyeater were analysed in this project at two contradicted sites, including their abundance, foraging behaviour and dietary requirements. Results obtained depicts a parallel link of honeyeater species abundance between the two studied sites. Wattled honeyeater are more abundant in

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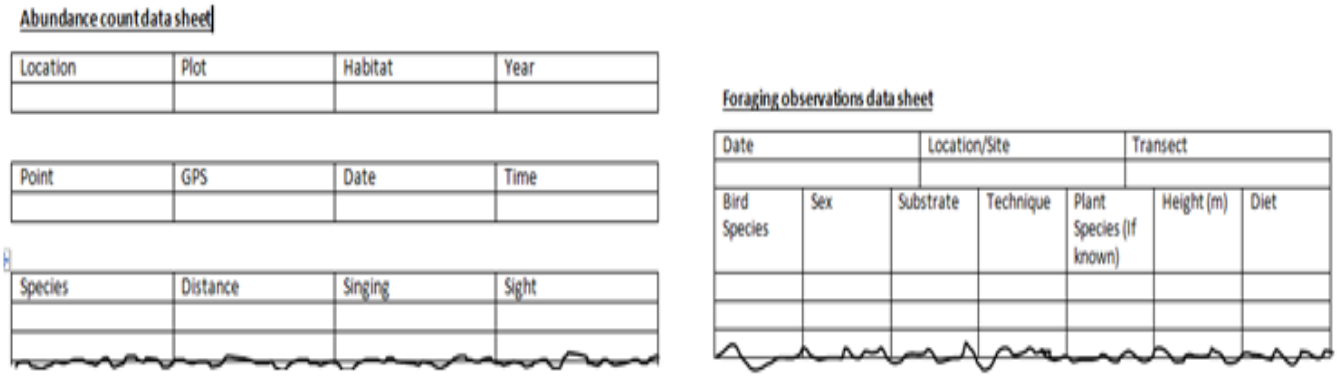
USP campus due to adequate nectar-producing plants compared to Colo-i-Suva Forest Reserve where they exhibited a wide range of foraging techniques on different forest strata and plant species. Orange-breasted myzomela are highly adaptable bird species which are frequently present in Colo-i-Suva Forest Reserve compared to USP campus where they resorted to diverse foraging techniques on different forest strata and plant species as well. Giant honeyeaters are limited to Colo-i-Suva Forest Reserve due to their habitual characteristics. This study further shows that there is a significant difference ($p < 0.05$) in abundance as well as between the number of honeyeater species in both sites across the forest vertical strata. However, there is no significant difference in foraging behaviour and the number of birds found foraging on diverse plant species ($p > 0.05$). The statistical analyses somewhat reveal a feeble conclusion as there were faults. We propose the following for future references; increase the survey distance and observation time, and include double observer at different time of the year (favourable weather conditions). Survey areas should be characterised and chosen based on several strict criteria's such that it doesn't influence bias in results. Studies of other vulnerable bird species are also relevant. Fiji houses rich diversity of avifauna, thus studying their ecology and behaviour is pivotal.

Supplementary



SFigure 1. Data sheets used during field survey for the abundance count and the foraging observations of honeyeater species.

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